SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2023
Project Title:	NUMERICAL INVESTIGATION OF CIRCULATION CHANGES IN THE NORTH WESTERN MEDITERRANEAN THROUGH DOWNSCALING OF CMEMS REANALYSIS DATA
Computer Project Account:	SPITBRAN
Principal Investigator(s):	Carlo Brandini Alessio Innocenti Michele Bendoni Valerio Capecchi
Affiliation:	CONSORZIO LAMMA / CNR
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….… ………………………………………………………….…
Start date of the project:	01/01/2022
Expected end date:	31/12/2024

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			8000000	0
Data storage capacity	(Gbytes)			6000	0

Summary of project objectives (10 lines max)

The objective of this project is to perform a high resolution downscaling of the circulation and biogeochemical reanalysis data (available through CMEMS) for the period 1987-2021 (physics) and 1999-2021 (biogeochemistry) over the North Western Mediterranean. Circulation and biogeochemistry will be modelled with the non-hydrostatic MITgcm model (Adcroft et al. 2018) coupled with the BFM biogeochemistry model (Vichi et al. 2015) through the BFMcoupler (Cossarini et al. 2017), while atmospheric forcing data were produced in a previous special project for the dynamical downscaling of the ERA5 reanalysis data (Vannucchi et al. 2021). The comparison of model results with multiple observations, such as HF radars, satellite data, temperature and salinity profiles, allow us to validate model performances. Downscaled dynamics will be employed to characterize long-term circulation trends in the coastal areas, and their impact on biogeochemical fluxes, in order to better understand the effect of climate change on coastal circulation and biodiversity.

Summary of problems encountered (10 lines max)

No significant problems related to the implementation and running of the model on the Atos platform were encountered in the period June-December 2022. Several computational experiments tested against observations to identify an adequate set of parameters (model calibration), starting from the values suggested in literature, were realised. Unfortunately Dr. Alessio Innocenti, the person who had contributed the most to the project, and who implemented the models on ATOS moved to a new job and, while maintaining his commitment to collaborate and transfer his expertise to others, he was for a long time unable to do so.

In the second part of the year, the working group will take charge of the simulations for the production of data, trying to respect the foreseen programme.

That is the main reason why, at present, the official SBU used in 2023 are still 0.

Summary of plans for the continuation of the project (10 lines max)

After the phase concerning model compilation and installation on the Atos cluster, we will perform several computational experiments tested against observations to identify an adequate set of parameters, starting from the values suggested in literature. Once the model setup will be defined, we will produce the dataset of the reanalysis, taking care to gradually check model results with respect to available observations.

As for the last 8 years of reanalysis many more information are available in the study area, mainly though HF radars measuring the surface currents on a large area, simulations will initially concern the years 2015-2023, while the older data, maintaining the model calibration configuration, will be reconstructed at a later time.

List of publications/reports from the project with complete references

From the former spitbran project, in continuity with the present one, a paper was published in Dec 2022:

Capecchi, V., Pasi, F., Gozzini, B., Brandini, C. A convection-permitting and limited-area model hindcast driven by ERA5 data: precipitation performances in Italy. CLIMATE DYNAMICS (2022).DOI: 10.1007/s00382-022-06633-2

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

For the SPITBRAN Special Project we are using the MITgcm circulation model coupled with the BFM biogeochemistry model through the BFMCoupler. The coupled software was compiled and tested on the Atos cluster, testing different compilers to find the best performances for the actual model. In particular we have compiled the model with the following set of combinations:

- gnu with openmpi;
- intel with openmpi;
- intel with intelmpi;

In a project planning to perform such long climatological analysis, at such high resolution, it is crucial to firstly assess the performances of the computing platform with the model, which might be largely different from our previous experience.

Model implementation

Starting from the original system setup, several steps and customizations were needed to develop the operational Ligurian Sea configuration, namely:
▪ definition of the domain and creation of the mask and bathymetry files;
▪ setup of the atmospheric forcings from the previous ERA 5 downscaling (see Capecchi et al., 2022) in the MITgcm required format, over the selected domain;
▪ setup of the river forcings from available databases;
▪ adaptation of the operational chain to the Atos cluster;
▪ initial calibration and validation in order to evaluate the accuracy of the system.

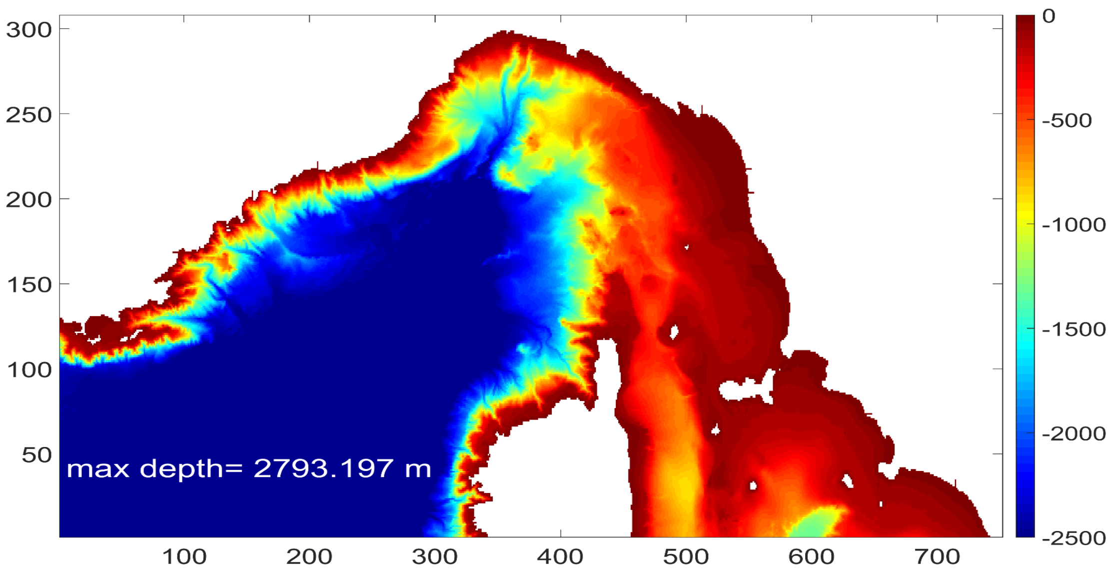

Fig.1: Bathymetry of the domain covering the Ligurian Sea and the Tuscan Archipelago.

The modal domain covers the Ligurian Sea with longitude ranging in 6.06-12.18°E and latitude in 41.88-44.50°N, with a resolution of 1/128°, resulting in a domain size of 784 x 336 grid cells in the

two horizontal directions with 60 vertical layers. Figure 1 shows the extension of the domain with the employed bathymetry. Once the horizontal resolution has been fixed to 1/128°, the extent of the domain to the South and West boundaries has been slightly adjusted in order to have a total number of cells in the x and y directions being a multiple of the number of cells in each MPI subdomain. Such setup is the same that is being used in the Interreg Med "Sharemed" project, where the present model has been made operational in various NWMed areas. In this way it will be possible to compare and cross-validate these first test runs of the model and to establish the performances of Atos cluster for this configuration, also with respect to another platform. With the results obtained in this first stage it will then be possible to find the optimum in terms of size and resolution in order to be able to cover the whole expected 34 years of hindcast as planned, taking into account the allocated SBU.
Concerning rivers, we have added the most important ones, using climatological data for the discharge rates. At the present stage the model preprocessing routines download automatically from CMEMS initial and boundary condition, cutting and interpolating the Mediterranean products on the restricted domain we are using. The same is done for the atmospheric forcing which are the BOLAM / MOLOCH models obtained from the downscaling done in a previous Special Project and still present on ecfs data storage.
The 2018 EMODNET bathymetry product has been used, which has a resolution of 1/16 × 1/16 arc minutes (around 115 x 115 m). The minimum depth is set to 3 m, while the maximum depth in the domain is 2810 m. River inputs were manually inserted in the Matlab script provided by Stefano Querin (OGS) and employed to build the bathymetry file. Each river was extended inland for a few cells in order to smoothen the transition at the river upstream boundary position (virtual "spring"). River beds have been rotated inland along the y axis in order to have only river boundary conditions from the North. The depth of all rivers was set to the minimal one (3 m), equivalent to 2 cells, and a width of one cell, which is enough to guarantee numerical stability (CFL criterion), due to the low discharge rates.

From the atmospheric model the following variables are used:
▪ u and v wind velocities at 10 meters height (m/s);
▪ temperature at 2 meters height (K); ▪ relative humidity (%);
▪ precipitation rate (kg/m2 /s);
▪ total cloud cover (%);
▪ mean sea level pressure (Pa);
▪ short wave downward radiation (W/m2);
▪ long wave downward radiation (W/m2).
Atmospheric forcing files are originally in grib format, one per each day and containing all variables. First of all, only the above variables are extracted from the grib files and are converted into NetCDF. Then, a Matlab script converts the files from NetCDF to the prescribed binary format for the MITgcm, producing one file per variable, containing the data for all the simulated days. In order to configure the model for using this set of variables, in the setup file used for model compilation, it is specified to use the third combination of variables which allows for the use of downward radiation fluxes, while net fluxes are computed by the model.

Results
Figures 2 to 6 show some examples of the results obtained from the operational model in the Ligurian Sea implementation. In particular, it is shown the hindcast for the day 11/11/2022 at 00 h . Results are shown for the surface modelled variables temperature, salinity, chlorophyll and nitrates. Model results are compared with CMEMS model output, and with satellite SST measurements (for temperature). We can notice that the increase in resolution is remarkable, with many structures that are represented by the HR Ligurian Sea model and not by CMEMS (Figures 2 and 4; Figures 5 and 6). On the contrary, macroscale features are well in accordance with CMEMS (which are also used as initial and boundary conditions), which means that our results do not drift significantly from the parent model, enhancing the stability of the operational system. Concerning temperature, we can also see a very good agreement with satellite SST (Figures 2-4).

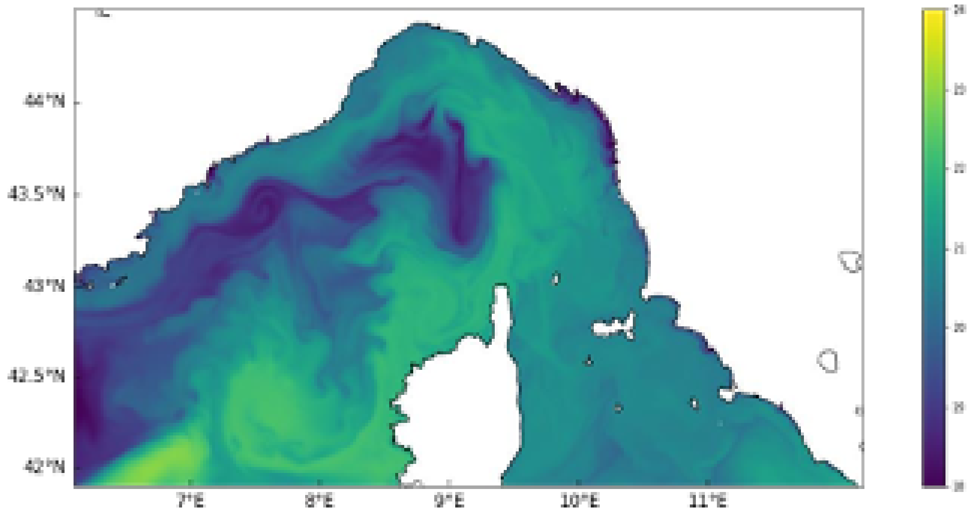

Figure 4 - Ligurian Sea surface modelled temperature on 11/11/2022 00h (hindcast of 11/11/2022 from CMEMS reanalysis).

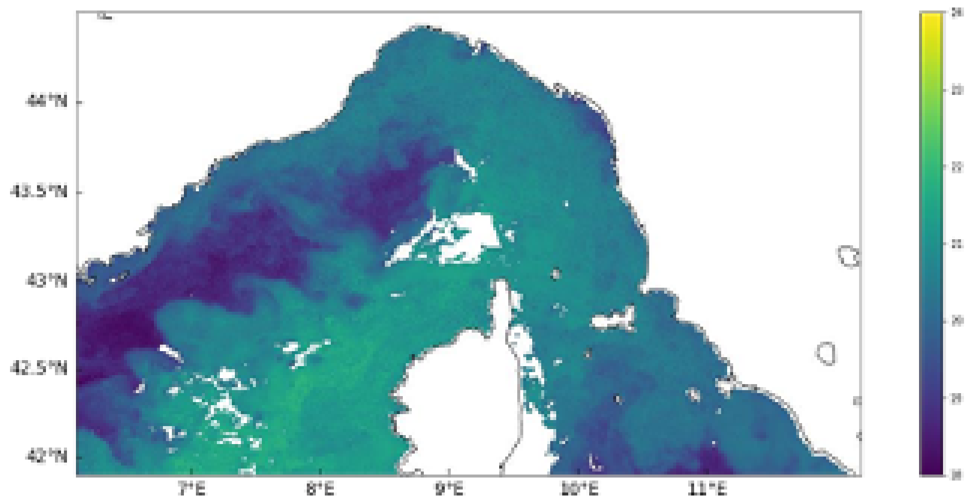

Figure 5 - SST L3 from satellite (CMEMS) on 11/11/2022 00h.

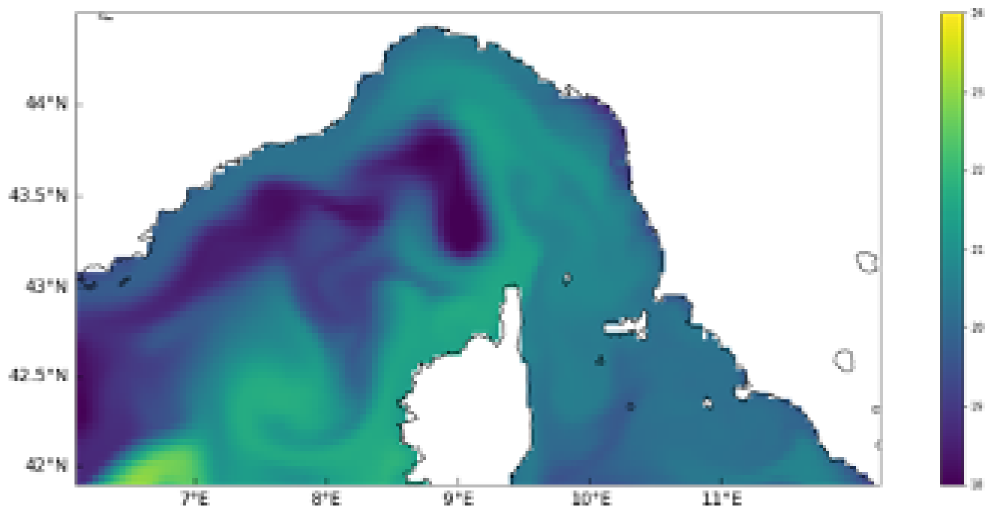

Figure 6 - CMEMS surface modelled temperature on 11/11/2022 00h.

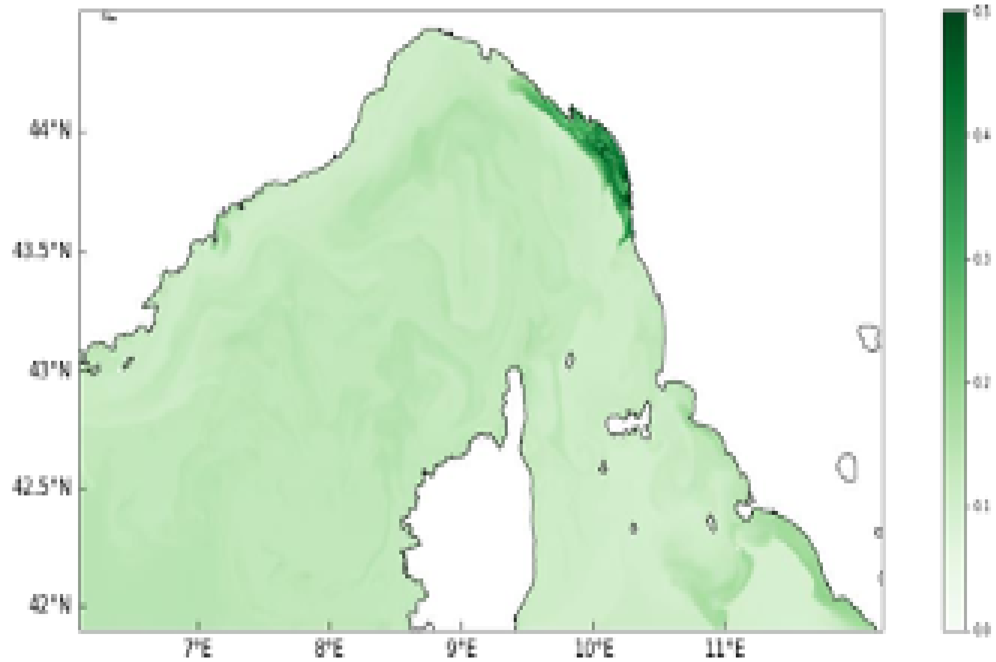

Figure 9 - Ligurian Sea surface modelled Chlorophyll-a concentration (mg/m3) on 11/11/2022 00h (hindcast of 11/11/2022).

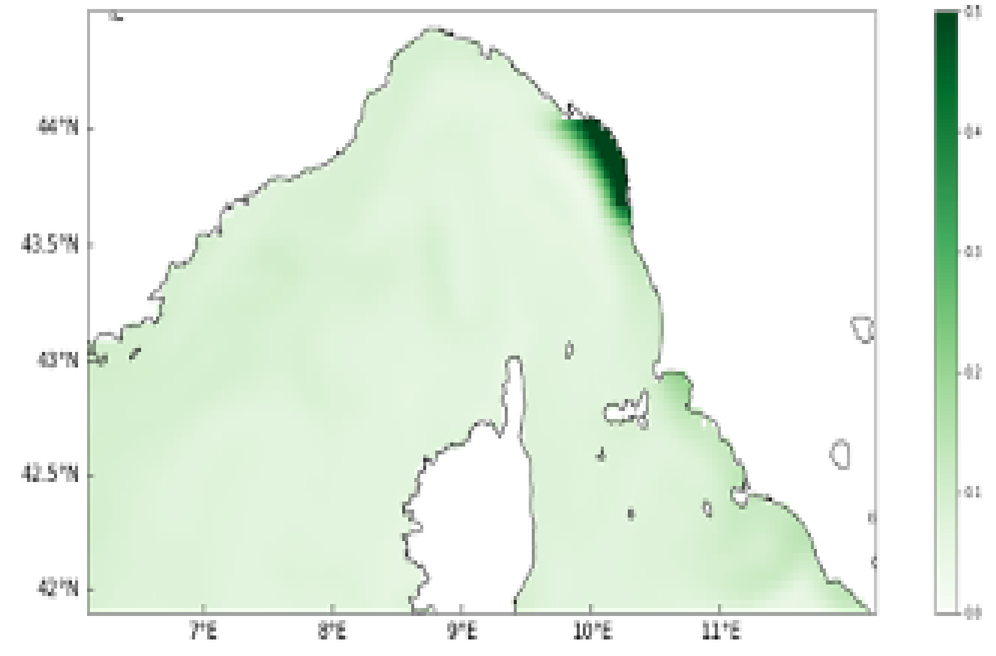

Figure 10 - CMEMS surface modelled Chlorophyll-a concentration (mg/m3) on 11/11/2022.

References

ADCROFT, Alistair, et al. MITgcm documentation. *Release checkpoint67a-12-gbf23121*, 2018, 19.

COSSARINI, Gianpiero, et al. Development of BFMCOUPLER (v1. 0), the coupling scheme that links the MITgcm and BFM models for ocean biogeochemistry simulations. *Geoscientific Model Development*, 2017, 10.4: 1423-1445.

VICHI, M., et al. The Biogeochemical Flux Model (BFM): equation description and user manual. *BFM version*, 2015, 5: 104.

VANNUCCHI, Valentina, et al. Dynamical downscaling of ERA5 data on the North-Western Mediterranean Sea: from atmosphere to high-resolution coastal wave climate. *Journal of Marine Science and Engineering*, 2021, 9.2: 208.